May 31, 1866.

Dr. WILLIAM ALLEN MILLER, Treasurer and Vice-President, in the Chair.

The following communications were read:—

I. "An Account of Experiments in some of which Electroscopic Indications of Animal Electricity were detected for the first time by a new method of experimenting." By CHARLES BLAND RADCLIFFE, M.D., Fellow of the Royal College of Physicians in London, Physician to the Westminster Hospital and to the National Hospital for Paralysis and Epilepsy, &c. Communicated by CHARLES BROOKE, M.A. Received March 15, 1866.

Very soon after the discovery of animal electricity by Galvani, Hemmer ascertained that electroscopic indications of electricity might be obtained at the surface of the human body. The instruments used in these investigations were the electroscope of Saussure and the condenser of Volta: the broad result arrived at was—that the indications in question might be sometimes present and sometimes absent; that they pointed sometimes to positive electricity, and sometimes to negative; and that they did not depend (except, perhaps, in a very small degree) upon the friction of the hair, or skin, or clothes, or carpet.

Upwards of sixty years have passed since Hemmer published the account of his labours. During the first half of this period not a little good work was done in this branch of scientific inquiry, especially by Gardini in 1792, by Ahrens in 1817, and by Nasse in 1834; and what was done is in the main confirmatory of the genuineness of the work done by Hemmer. During the last thirty years, on the contrary, little or nothing has been done*. It seems, indeed, as if the discovery of the galvanometer, now a little more than thirty years ago, had diverted attention from the electroscope: at any rate it is the fact that it has been the fashion since the discovery of the galvanometer to forget the static, and to think only of the current phenomena of animal electricity. Nor is this altogether to be wondered at; for it must be allowed that the facilities for detecting the current phenomena of animal electricity are far, very far greater than those for detecting the static phenomena of this agent. Be this as it may, however, my own experience amounts to this—that I found it difficult to

* One exception to this statement must be made in favour of some recent investigations by Dr. Meissner, of which an account is given in an article entitled "Ueber das electrische Verhalten der Oberfläche des menschlichen Körpers," in Henle and Pfeufer's 'Zeitschrift für rationelle Medicin.' Dritte Reihe, Band xii. 1861. These investigations seem to be very deserving of careful study, and I much regret that my attention was only for the first time directed to them in some remarks which followed the reading of this paper at the Meeting of the Royal Society.

detect these latter phenomena easily and satisfactorily until I hit upon the method of investigation employed in the experiments about to be described—a method which dispenses with the use of the condenser, which appears to be as delicate as it is certain and simple, and which I now proceed to describe without any further preamble.

I. *An account of the method of experimenting employed in the experiments which have to be related presently.*

In order to carry out this method of experimenting, the instruments necessary are two small electroscopes, two insulating stands upon which to fix these electroscopes, and a conducting rod with an insulating handle. Each electroscope is provided in the usual way with a pair of gold leaves, and with slips of tinfoil in the interior of the glass bell of the instrument, and it has, in addition, an opening underneath the wooden base, by which it may be screwed on the top of the insulating stand. Each insulating stand is a piece of glass rod 9 or 10 inches in length, fixed by its lower end into a suitable foot, and having at the upper end a screw which fits into the opening underneath the wooden base of the electroscope. In one stand (for reasons which will appear presently) the glass stem is varnished; in the other it is left unvarnished. The conducting rod may be of any form. For the rest, all that need now be said is that, in order to avoid the chance of electricity being developed by the friction of lackered surfaces, the caps of the electroscopes, and the end of the conducting rod which has to be brought into contact with the caps at certain times, are left unlackered, and that, in order to secure as good insulation as possible, the exterior of the electroscopes are well varnished whenever practicable.

In preparing for an experiment, the electroscopes are screwed on the insulating stands, and then charged in a particular way with free electricity—the one with free positive electricity, the other with free negative electricity. This charge is obtained by gently rubbing the glass stem of the insulating stands between the finger and thumb—the positive electricity from the unvarnished glass stem, the negative from that which is varnished. The electricity thus obtained is communicated, not to the cap, which is in direct communication with the gold leaves, but through the wooden base to the tinfoil slips which run halfway up the interior of the glass bell of the electroscope; and thus, instead of being charged directly, the gold leaves become charged *inductively* with the opposite kind of electricity to that which is communicated to the tinfoil slips. The result of doing this is that the gold leaves take up a given degree of divergence, and that they remain divergent so long as the tinfoil slips retain their charge of electricity. Charged in this manner, in fact, the gold leaves cannot be brought together by placing a conductor between the cap of the electroscope and the earth; indeed, so far from this being possible, the effect of placing a conductor in this position, under these circumstances, is (as may easily be understood) to increase the divergence of the gold leaves.

Now what has to be done in preparing for an experiment is to get the gold leaves in that second position of divergence into which they pass when the discharging rod is applied to the cap of the charged electroscope. First of all, the gold leaves are made to diverge to a given degree by charging the electroscope in the manner which has been described; then the conducting rod is placed in position and the gold leaves are made to take up the full degree of divergence by so doing; and when this is done the electroscopes are ready for use.

The electroscopes being "set" in this manner, the experiment which has to be performed consists in bringing the body, whose electrical condition has to be examined, to the cap of each electroscope in turn, and in noting the movements of the gold leaves. The experiment is simple, and the results are these. When the body is electrified positively, it causes increased divergence of the gold leaves in the electroscope in which these leaves are electrified with positive electricity; and *vice versâ*, when the body is electrified negatively, it causes increased divergence of the gold leaves in the electroscope in which these leaves are electrified with negative electricity, and diminished divergence in the electroscope in which these leaves are electrified with positive electricity. These are, as will be easily understood, the movements of the gold leaves which must take place under these circumstances. Moreover the charge of electricity in the electroscope reacts upon the body which is brought to the cap of the instrument, and produces, in a way which is intelligible enough, a certain small amount of increased divergence of the gold leaves of *both* electroscopes. Now this slightly increased divergence of the gold leaves in *both* electroscopes is of little or no moment when bodies electrified with comparatively large amounts of free electricity are made to act upon the caps of the instruments, but it is of great moment when these bodies are electrified with minute amounts of free electricity; for in this case the movements of the gold leaves arising from the action of the free electricity will be exaggerated or masked according as they happen to be in the same direction or in the opposite direction to the movements produced by the reaction of the charge in the electroscopes. Thus, if the degree of increased divergence in the gold leaves of *both* electroscopes arising from the reaction of the charge in the instruments be $=2$, and if the alteration in the divergence of the gold leaves produced by the action of free electricity be of the same value, that is $=2$, the result of this latter action will be, not increased divergence of the gold leaves $=2$ in one electroscope, and diminished divergence of these leaves $=2$ in the other instrument, but increased divergence $=4$, in the electroscope in which it causes increased divergence (for in this case it is the action of the free electricity *plus* that of the reaction of the charge in the instrument, $2+2=4$), and no alteration of divergence in the electroscope in which it causes diminished divergence (for in this case it is the converging action of the free electricity *minus* that of the diverging action of the charge in the instrument, that is, $2-2=0$),

—and so also in similar cases, the movement of increased divergence of the gold leaves in both electroscopes arising from the reaction of the charge in the instrument being added to or subtracted from the movement of the gold leaves produced by the action of free electricity, according as these movements happen to be in the same or in opposite directions.

These, then, being the facts, it is easy to see how, by using two electroscopes, it is possible to eliminate the reaction of the charge of electricity in the instruments upon the gold leaves, and to make this reaction tell in making more obvious the action of very minute quantities of electricity. It is easy to eliminate the reaction of the charge of electricity in the electroscopes upon the divergence of the gold leaves; for this reaction causes slightly increased divergence of these leaves in *both* instruments. It is easy to make the reaction of the charge of electricity in the electroscopes upon the divergence of the gold leaves tell in making more obvious the action of free electricity upon the divergence of these leaves; for it is plain that in the electroscope in which the action of positive electricity causes increased divergence of the gold leaves, this movement will be aided by the increased divergence of these leaves arising from the reaction of the charge of electricity in the electroscopes, and, *vice versâ*, that in the electroscope in which negative electricity causes increased divergence of the gold leaves this movement will be aided by the increased divergence of these leaves arising from the reaction of the electricity in the instrument. Nor does it follow that one of the electroscopes is in reality superfluous. *A priori*, indeed, it might be supposed that one electroscope would be sufficient. It might appear enough to take the movements of increased divergence of the gold leaves as evidence of the action of one kind of electricity, and the movements of diminished divergence as evidence of the other kind of electricity. But when dealing with minute quantities of electricity, it is found practically that the movements of diminished divergence are not so easily produced as those of increased divergence, and that there are impediments to free movement in this direction, arising from the clashing of the movement of diminished divergence due to the action of free electricity with the movement of increased divergence due to the reaction of the charge of electricity in the electroscope. In short, the plain truth appears to be, not only that the two electroscopes act as a check upon each other, and show the same thing from two different points of view, but that they furnish evidence which in itself is far more conclusive, when dealing with minute quantities of electricity, than can be got from either instrument singly.

In the description of the experiments upon which I am now about to enter, it is necessary to be able to distinguish the two electroscopes the one from the other; and I propose, therefore, to speak of the instrument in which the gold leaves are charged with positive electricity, and in which positive electricity causes increased divergence of these leaves, as the *Positive Electroscope*, and of the instrument in which the gold leaves are charged

with negative electricity, and in which negative electricity produces increased divergence of these leaves, as the *Negative Electroscope.*

II. *An account of experiments in some of which electroscopic indications of animal electricity were detected by the method of experimenting which has just been described.*

In this account the degree of movement of the gold leaves is indicated by arbitrary figures. It is assumed also that the increased divergence of the gold leaves in *both* electroscopes, which movement has been seen to arise from the reaction of the charge of electricity in the electroscope, is $=2$; and in each experiment this figure is added to the movement produced by the action of free electricity in the case where this action causes increased divergence of the gold leaves, and subtracted in the case where this action causes diminished divergence of these leaves. Thus, in the case where the movement of the gold leaves arising from the action of free electricity is $=3$, the actual movement of the gold leaves in the instrument in which there is increased divergence of these leaves will be $=5$, for $3+2=5$, and in the instrument in which there is diminished divergence of these leaves will be $=1$, for $3-2=1$. Or, in the case where the movement due to free electricity is $=1$, there will be a different degree of *increased* divergence of the gold leaves in *both* electroscopes; for in the instrument in which the action of the free electricity causes increased divergence, the actual movement of the gold leaves will be $=3$, for $1+2=3$; and in the instrument in which this action tends to cause diminished divergence, this tendency will be overpowered by the increased divergence due to the reaction of the charge of electricity in the electroscope, and the actual movement which results will be one of increased divergence $=1$; for the movement of increased divergence arising from the reaction of the charge in the electroscope, $=2$, *minus* the movement of diminished divergence, $=1$, arising from the action of the free electricity, must be increased divergence $=1$, for $2-1=1$.

In the account of these experiments, also, certain abbreviations are made use of: thus i. d. stands for increased divergence of the gold leaves, d. d. for diminished divergence of those leaves.

For the rest, I have only to add that these experiments, which I leave to tell their own story, with the aid only of a few short comments at the end of each series, supply the first electroscopic indications of electricity in living blood and in living nerve-tissue, and that, to say the least, they clear up all uncertainty as to the presence in the living human body and in living muscular tissue of electricity capable of supplying like indications.

First Series.—Experiments which furnish electroscopic indications of electricity in the living human body.

In the first four of these experiments all that was done was to apply the palm of my hand or the tips of my fingers to the cap of each electroscope

in turn, and to note the movements of the gold leaves produced by so doing. In the fifth experiment, the part experimented upon was brought to the caps of the electroscopes by taking hold of a loop of silk braid which had been previously attached to it.

Exp. 1.—In this case the result was d. d. $=4$ in the negative electroscope, and i. d. $=8$ in the positive electroscope,—a result showing, as has been already explained, that the electroscopes were acted upon by positive electricity $=6$.

Exp. 2.—Here the movements of the gold leaves indicated the action of positive electricity $=2$, the facts being—no alteration of the divergence of the gold leaves in the negative electroscope, and i. d. $=4$ in the positive electroscope.

Exp. 3.—In this case there was i. d. $=2$ in *both* electroscopes—a state of things showing that the hand was electrically neutral at the time, seeing that the movements of the gold leaves were only those which were due to the reaction of the charge of electricity in the electroscopes.

Exp. 4.—Here there was no alteration of the divergence of the gold leaves in the positive electroscope, and i. d. $=4$ in the negative electroscope—a state of things (the reverse of what happened in Exp. 2) signifying that the electroscopes were being acted upon by negative electricity $=2$.

Exp. 5.—A part of a foot which had been removed by amputation from a patient in the Westminster Hospital twenty-four hours previously was the part experimented upon in this instance; and the result was the same as in Exp. 3, namely, i. d. $=2$, in *both* electroscopes equally—the result which is brought about when a body which is electrically neutral is brought to the caps of the electroscopes.

*** I have performed experiments like the first four many hundred times, and I have repeatedly tested in the same way the electrical condition of other persons. In the great majority of instances the electroscopic indications were those of positive electricity. Only now and then all electroscopic indications were absent. I have also on several occasions repeated the experiment on portions of the dead body, and always without finding any signs of electricity. More than once, on the same occasion, I have found strong indications of positive electricity in one person, and very feeble indications, or no indications whatever, in another person. More than once also I have been able to detect electricity in my own body, or in the bodies of other persons at an elevation of some feet above the ground, when it was impossible to do so on the ground itself. In fact I have obtained proof of the existence of great variations in the electricity of myself and others at various times and under various circumstances, and I have begun a systematic series of observations with a view to ascertain the electrical condition of the human body at different times and under different circumstances as to health and disease. I have already in this way arrived at some curious results, and I have certainly seen enough to make me hope that a knowledge of the electrical changes in human bodies may

shed much light upon the changes which are continually taking place in the vital condition of the human body, especially when the electrical changes within the body are taken in connexion with electrical and other changes without the body.

Second Series.—Experiments which furnish electroscopic indications of electricity in living blood.

The blood used in this series of experiments was collected in a wide-mouthed glass bottle capable of holding about 2 oz. Immersed in the blood and projecting to a convenient distance from the neck of the bottle, was a piece of platinum wire. The bottle was provided with a loop of silk braid, which loop was fastened in such a way as to allow the bottle to be lifted up by it without spilling the contents; and the necessary communication with each electroscope in turn was made by taking hold of the loop and by bringing the platinum wire projecting from the mouth of the vessel into connexion with the cap of the instrument.

Exp. 6.—In this case the blood used was from the internal jugular vein of a donkey, and the electroscopic indications obtained were those of negative electricity = 6,—the actual movements of the gold leaves being d. d. = 4 in the positive electroscope, and i. d. = 8 in the negative electroscope.

Exp. 7.—Here the blood was from the internal carotid artery of the same donkey which had furnished the venous blood used in the last experiment; and the result was also the same, namely, d. d. = 4 in the positive electroscope, and i. d. = 8 in the negative electroscope,—a result denoting the action of negative electricity = 6 upon the instruments.

Exp. 8.—In this experiment blood from the carotid artery of a sheep was examined; and the movements of the gold leaves were those of positive electricity = 2, there being no alteration of the divergence of the gold leaves in the negative electroscope, and i. d. = 4 in the positive electroscope.

Exp. 9.—Here the blood used was from the carotid artery of a dog. The examination was made without loss of time, and the animal seemed to be in good health; but all signs of electricity in the blood were absent, the movements of the gold leaves being those of i. d. = 2 in both electroscopes equally.

Exp. 10.—The blood experimented upon in this case was that which had been already used in Exp. 6, an interval of an hour and a half having elapsed between the two experiments. In the former experiment the blood gave electroscopic indications of negative electricity = 6; in this instance these indications had disappeared altogether, for there was i. d. = 2 in *both* electroscopes equally.

*** I have repeated experiments like these many times upon the blood of various animals—oxen, sheep, dogs, rabbits, and so on—sometimes upon pure arterial blood, sometimes upon pure venous blood, more frequently upon the mixed stream which follows the knife of the butcher in the ordinary process of slaughtering sheep and oxen. As a rule, I have found

decided electroscopic indications of negative electricity indifferently in arterial, venous, or mixed blood; not unfrequently I have failed to find any such signs. Now and then I have found comparatively feeble signs of positive electricity. In every case also where I have examined blood after an interval of an hour or so from the time when it had flowed fresh from the vessel, I failed to detect any sign of electricity, negative or positive. These experiments no doubt leave much to be discovered in the same direction, but this at least they do,—they furnish the first electroscopic proof of the presence of electricity in living blood. Nay, it is perhaps not too much to say that they supply the first unequivocal proof of electricity in blood, for the current electricity recently obtained from blood by M. Scoutteten and Dr. Shettle *may* in reality be nothing more than the result of chemical and other changes produced by the blood upon the terminal wire of the galvanometer used in these experiments.

Third Series.—Experiments which furnish electroscopic indications of electricity in living nerve-tissue.

The plan adopted in this series of experiments was to tie a loop of silk braid to the part to be experimented on, and to use this loop as the means for bringing this part to the cap of each electroscope in turn.

Exp. 11.—The medulla oblongata of an ox obtained a few minutes after the animal had been killed in the ordinary way in the shambles, was the part used in this experiment. At one time the cut surface exposing the transverse section of the fibres and the internal grey matter was brought to the caps of the electroscopes; at another time the uncut surface corresponding to the longitudinal surface of the fibres was treated in this manner; and in each case the movements of the gold leaves were indicative of the action of positive electricity = 6, or thereabouts, the only difference perceptible being a slight one of degree. The average movements obtained were those of d. d. = 4 in the negative electroscope, and i. d. = 8 in the positive electroscope.

Exp. 12.—The brachial enlargement of the spinal cord of an ox, taken out of the canal when the carcass was being split into two lateral halves at the usual time, that is, about half an hour from the moment when the animal had been felled with the pole-axe, was used in this experiment, and the result was d. d. = 4 in the negative electroscope, and i. d. = 8 in the positive electroscope. It was found also that this result was the same, except in some trifling difference in degree, in the case where the transverse sectional surface of the fibres was brought to the caps of the electroscopes, and in the case where the longitudinal surface of these fibres, natural or artificial, was examined in this manner.

Exp. 13.—Here the part examined was the posterior lobe of the cerebrum of a sheep which had been killed in the usual way a few minutes previously in the shambles. No time was lost in making the necessary preparations, but not the slightest indications of electricity were obtainable,

the movements being only those of i. d. = 2 in both electroscopes equally.

Exp. 14.—The cerebellum of a sheep was examined in this experiment, and the result was—no alteration in the divergence of the gold leaves in the negative electroscopes, and i. d. = 4 in the positive electroscopes, a state of things indicating the action of positive electricity = 2 upon the instruments. It was ascertained also that all parts of the cerebellum indifferently behaved in the same manner.

Exp. 15.—In this experiment the brain of a donkey just killed by loss of blood was examined, and it was found that all parts of the surface indifferently, natural or artificial, gave similar indications of negative electricity = 4, there being d. d. = 2 in the positive electroscope, and i. d. = 6 in the negative electroscope.

Exp. 16.—The brain of the donkey used in the last experiment was used also in this instance, an interval of an hour, or thereabouts, having elapsed between the two experiments. When first examined this organ gave indications of negative electricity = 4; now it was found to have lost all traces of electrical activity everywhere, for the movements of the gold leaves were simply those of i. d. = 2 in *both* electroscopes equally.

⁂ These experiments, as I believe, bring to light a new fact, inasmuch as they furnish the first electroscopic proof of the presence of electricity in living nerve-tissue. Judging from these and several other experiments of the same kind, in which dogs and rabbits, as well as oxen, sheep, and donkeys, were put under contribution, it would seem that living nerve-tissue, as a rule, furnishes electroscopic signs of electricity, sometimes positive and sometimes negative in character, and that these signs are always absent when the nerve-tissue may be supposed to have lost all traces of vitality. And this also would seem to be a conclusion deducible from the same evidence—that all parts of the nerve-tissue present signs of the *same kind* of electricity. It would seem, in fact, as if these experiments suggested a conclusion which is at variance with a conclusion drawn by Professor Du Bois Reymond from some of his experiments. Watching the direction of the "nerve-current" which passes through the galvanometer between the longitudinal surface, natural or artificial, of the nerve-fibres, and the transverse sectional surface of these fibres, Professor Du Bois Reymond comes to the conclusion that these two surfaces are in opposite electrical conditions, the one being positive, the other negative. Because the current passes in a particular direction, he infers that these surfaces must be electrified with different kinds of electricity. But it is plain that the current might pass between parts electrified with *different degrees* of the *same* electricity; and indeed M. Du Bois Reymond himself explains the current passing between two points of the same surface in this manner; and therefore, even on his own showing, there is no necessity to suppose that the longitudinal surface of the nerve-fibres is electrified with one kind of electricity and the transverse sectional surface

of the fibres with the other kind. At any rate, the facts revealed by the electroscope do not appear to be of doubtful significance, and the only inference which I can deduce from them is that every part of the surface of living nerve-tissue, natural or artificial, furnishes signs of the same kind of electricity, and that the only electrical differences between one part and another are nothing more than differences of degree.

Fourth Series.—Experiments which furnish electroscopic indications of electricity in living muscular tissue.

In this series of experiments the mode of proceeding was the same as that adopted in the last series.

Exp. 17.—The piece of muscle examined in this experiment was cut out of the sterno-mastoid of an ox a few moments after the animal had been killed in the shambles, and every part of the surface was tested in turn, and, except in some trifling difference in degree, the movements of the gold leaves were in all cases indicative of the action of positive electricity = 6, these movements being those of d. d. = 4 in the negative electroscope, and those of i. d. = 8 in the positive electroscope.

Exp. 18.—Here the sterno-mastoid of a sheep just killed in the ordinary way in the shambles, furnished the material for experiment, and the result was—no alteration in the divergence of the gold leaves in the negative electroscope, and i. d. = 4 in the positive electroscope—a result showing the action of positive electricity = 2 upon the electroscopes.

Exp. 19.—In this instance the portion of muscle examined was taken from the glutæus maximus of a donkey which had just been killed by hæmorrhage, and it was found that all parts of the surface indifferently supplied indications of negative electricity = 1, the movements of the gold leaves being those of i. d. = 1 in the positive electroscope, and i. d. = 3 in the negative electroscope.

Exp. 20.—A piece of the left ventricle of the heart of a dog just dead from hæmorrhage was examined in this instance, and the only movements of the gold leaves were those which are produced by the action of a body electrically neutral, namely, i. d. = 2 in both electroscopes equally.

Exp. 21.—Here the piece of muscle experimented upon was that used in Exp. 17. Twelve hours had elapsed between the two experiments, and *rigor mortis* had now fully set in, and the result showed that the positive electricity which was present formerly was no longer present, the movements of the gold leaves being simply those of i. d. = 2 in both electroscopes equally.

⁂ With the exception of an experiment in which Professor Matteucci incidentally states that he obtained "signes de tension avec un condensateur délicat" from one of his "muscular piles," these experiments furnish, so far as I know, the only electroscopic indications of the presence of electricity in living muscular tissue—perhaps the very first really *distinct* proofs of this fact. I have repeated these experiments several times on

the muscles, living and dead, of various animals, oxen, sheep, donkeys, dogs, and rabbits, and I have found in the great majority of instances that all parts of the surface of living muscle furnished indications of the same kind of electricity, that this electricity was sometimes positive, sometimes negative, and that these signs were invariably absent in muscle which had passed into the state of *rigor mortis*. These experiments, moreover, make it difficult to agree with Professor Du Bois Reymond in thinking that the longitudinal surface, natural or artificial, of the muscular fibres, and the transverse sectional surface of these fibres, are electrified with different *kinds* of electricity. With respect to the electricity of muscular tissue, indeed, it seems to be precisely as it is with respect to the electricity of nerve-tissue, namely this, that all parts of the surface are electrified with the same kind of electricity, positive or negative, as the case may be, the only difference between one part and another being one of degree; and the comments upon M. Du Bois Reymond's conclusions, when speaking upon the condition of nerve-tissue as to electricity, are equally applicable to the present case, if only the words muscular tissue and muscular current be substituted for nerve-tissue and nerve-current.

In conclusion, it only remains for me to direct attention to one bearing of the facts recorded in this paper. These facts, one and all, exhibit animal electricity, not in the form of a feeble nerve-current, or of a feeble muscular current, or of the still feebler currents of less definite character, but as endowed with a considerable amount of tension. They bring to light a property of animal electricity which is more intelligible on the supposition that the *primary* condition of this electricity is not current but statical. It is easy to account for these phenomena of tension if the primary condition of animal electricity be statical, for tension is the characteristic property of statical electricity; it is by no means easy to account for these phenomena of tension if the primary condition of animal electricity be that of the current revealed by the galvanometer, for the currents so revealed are far too feeble to allow one to suppose that they can be endowed with an appreciable amount of tension. In a word, with the phenomena of tension to account for which are revealed in the experiments recorded in this paper, the natural inference, as it seems to me, is that the primary condition of animal electricity is, not current, but statical, and that the currents made known by the galvanometer to which so much attention has been paid of late—the muscular current, the nerve-current, and the rest—are *secondary* phenomena developed accidentally by placing the ends of the coil of the galvanometer so as to include points in which the electricity is different in degree. Nay, it would seem that these currents may in reality be a retarded discharge of statical electricity, for it is a fact that they cannot be detected without a coil of which the wire is so long and so fine as to be capable of giving sufficient resistance to bridle a discharge

into the quieter pace of ordinary currents*. Many important consequences in physiology and in pathology, as I think, result directly or indirectly from this view of the matter, of which some are set forth in some Lectures which I gave at the College of Physicians in London three years ago, and which have since appeared in print; but it is no part of my present task to consider these consequences. Indeed, what I proposed to do in this paper I have now done; and this was simply to direct attention to certain facts as facts, and to offer certain passing comments suggested naturally by these facts.

II. "On the Dynamical Theory of Gases." By J. Clerk Maxwell, F.R.S. L. & E. Received May 16, 1866.

(Abstract.)

Gases in this theory are supposed to consist of molecules in motion, acting on one another with forces which are insensible, except at distances which are small in comparison with the average distance of the molecules. The path of each molecule is therefore sensibly rectilinear, except when two molecules come within a certain distance of each other, in which case the direction of motion is rapidly changed, and the path becomes again sensibly rectilinear as soon as the molecules have separated beyond the distance of mutual action.

Each molecule is supposed to be a small body consisting in general of parts capable of being set into various kinds of motion relative to each other, such as rotation, oscillation, or vibration, the amount of energy existing in this form bearing a certain relation to that which exists in the form of the agitation of the molecules among each other.

The mass of a molecule is different in different gases, but in the same gas all the molecules are equal.

The pressure of the gas is on this theory due to the impact of the molecules on the sides of the vessel, and the temperature of the gas depends on the velocity of the molecules.

The theory as thus stated is that which has been conceived, with various degrees of clearness, by D. Bernoulli, Le Sage and Prevost, Herapath, Joule, and Krönig, and which owes its principal developments to Professor Clausius. The action of the molecules on each other has been generally assimilated to that of hard elastic bodies, and I have given some applica-

* It is to be supposed that certain molecules in living animal bodies are, under certain given conditions, a constant source of electricity—are so, perhaps, in the way in which certain molecules of the electrophorus are such a source. The idea is that this electricity is so supplied as to admit of a series of frequent discharges, or to keep up a constant current if these discharges are retarded sufficiently. At any rate, it does not follow that this constancy of the current of animal electricity detected by the galvanometer is an objection in itself to the idea that the primary condition of animal electricity may be, not current, but statical.